NUMERICAL MODELLING OF MICROWAVE DRIED POTATO FLAKES

Lucaci Codruţa, Coman(Vica) Simina*, Daroczi Karoly**
* University of Oradea, Faculty of Environmental Protection,
26 Gen.Magheru Street, Oradea, 410059,
Romania, e-mail: simina_vicas@yahoo.com

ABSTRACT

During the research was developed using the commercial software Ansoft HFSS (High Frequency Structure Simulation) a numerical modeling of a microwave system having as a dielectric material the potato flakes. Using numerical modeling software's there can be simulated the dielectric products to test appropriate microwave treatment control strategies.
Keywords: Ansoft HFSS, microwave drying, dielectric properties, numerical modeling

1. INTRODUCTION

Microwaves are electromagnetic waves in the frequency band from 300 MHz (3×10^8 cycles/second) to 300 GHz (3×10^{11} cycles/second) (Hathazi and Maghiar, 2003). Microwave processing materials at industrial level Industrial microwave processing is usually done at the frequencies set aside for industrial use, 915 MHz, 2.45 GHz, 5.8 GHz, and 24.124 GHz (Maghiar and Soproni, 2003), (Metaxas and Meredith, 1983).

The process of drying materials in the microwave field has become a new, powerful, and significantly different tool which has significant advantages in front of the drying conventional methods (Metaxas and Driscol, 1974), (Molnar et al, 2008). The conventional heating methods require heat conduction from the material's surface inward, they are slow and inefficient for materials that conduct heat poorly (Khraisheh, 2004).

The application of microwave energy to the processing of various materials such as ceramics, metals and composites offers several advantages over conventional heating methods (Nelson, 1995). These advantages include unique microstructure and properties, improved product yield, energy savings, reduction in manufacturing cost and synthesis of new materials (Das et al, 2009).

First controlled and used during the second world war in radar systems, the usefulness of microwaves in the heating of materials was first recognized in 1946 (Soproni et al, 2009). Raytheon introduced the first microwave oven to the marketplace in 1952. A large investment has been made over many years in the development of microwave processing systems for a wide range of product applications (Sablani and Mujumdar, 2006) (Phillippy, Mengshi and Rasco, 2004).

2. MATERIAL AND METHODS

Dielectric properties of food materials depend on many factors, including frequency of the microwaves, food temperature, moisture content, salt content, and other constituents (Juming Tang, 2012). In a food system, the change of dielectric properties with respect to temperature depends upon frequency, bound water to free water ratio, ionic conductivity, and composition of the material (Szabo, Rajko and Hodur, 1998). For example, at microwave frequencies used by the food industry, both the dielectric constants and the loss factor due to polarization of bound water in foods would increase with temperature. On the other hand, these two properties of free water would decrease when temperature increases (see fig.1) (Juming Tang, 2012).

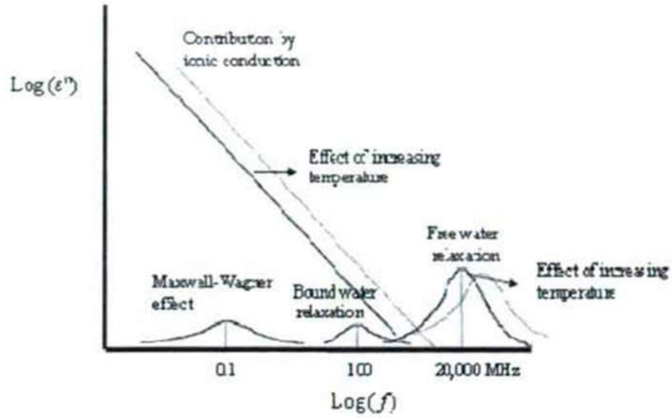

Figure1. Contributions of various mechanisms to the loss factor of moisture materials as a function of frequency and temperature (Juming Tang, 2012)

The dielectric properties of materials are being described by the complex relative permittivity, ε^*, which is represented with the next relationship:

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \tag{1}$$

where $j = \sqrt{-1}$;

ε' represents the dielectric constant and is the ability of the material to store electric energy when in an electromagnetic field;

ε'' represents the imaginary part, it is the dielectric loss factor and influences the conversion of electromagnetic energy into thermal energy.

The ratio of the real and imaginary parts of permittivity represents the tangent of loss angle $\tan\delta = \varepsilon' / \varepsilon''$ which along with the dielectric constant determines the attenuation of microwave power in foods.

In the electromagnetic field, the amount of thermal energy converted in food is proportional to the value of the loss factor ε''. The increase in temperature (ΔT), without consideration of heat transfer, can be calculated from:

$$pC_p \frac{\Delta T}{\Delta t} = 5.563 \times 10^{-11} fE^2\varepsilon'' \quad (5.563*10^{-11} = 2\pi\varepsilon_0) \tag{2}$$

where

$C_p (Jkg^{-1}\,{}^0C^{-1})$ is the specific heat of heated material;

$\rho(\text{kg m}^{-3})$ is the density;

$E(\text{Vm}^{-1})$ is electric field intensity

f(Hz) is frequency

Δt(s) is time increment

$\Delta T({}^0C)$ is the temperature rise (Schubert and Regier, 2005).

The most important vegetable crop, the fourth as importance in the world is the potatoe and the main utilization of processed potatoes includes table stock (31%), frozen French fries (30%), chips and shoestrings (12%), and dehydrated items (12%) (Miranda and Aguilera, 2006).

The chemical composition of potato varies with cultivar, location of growth, agricultural practices, maturity at harvest, and subsequent storage history, among others. Potatoes are mainly made up of water (75% on average) (Friedman, 2003).

3. RESULTS AND DISCUSSIONS

In the process of developing technologies based on microwave energy, an important step is creating experimental models, lab, that could permit a real analyze of the phenomenon's in any moment and conditions of the heating process with microwaves and also determining the specific parameters of the problem.

The existence of special software's permit that before practically making an installation, it can be numerical simulated. In this way when creating the installation there will be known a part of the phenomenon's that characterize the installation, and so there will be eliminated some of the unknown's of the problem.

The existing resonant cavity was numerically simulated using the commercial software Ansoft HFSS, and the obtained results are being presented below.

The monomod aplicator has a parallelipiped shape, made of aluminium walls and is being excited by a magnetron at a frequency of 2.45GHz. Electromagnetic waves transmission from the magnetron to the cavity is being made through a rectangular waveguide, in which prolongation is placed the applicator.

The commercial software Ansoft HFSS is a interactive software that allows electromagnetic field determination inside passive structures at high frequencies. ANSYS is the leading provider of electromagnetic field, circuit and system simulation software for the design of high-performance electronic equipment and electromechanical devices.

For analyzing the electromagnetic field inside the microwave installation, were homogenized 100g of potato flakes with 600 ml of water in a plastic recipient, that was preliminary weighted and than the composition was introduced in the microwave at a variable power, processing time being of 5 minutes.

Accordingly to the specialty literature the values for the relative permittivity and loss factir for wet potato flakes at a temperature of 20° are $\varepsilon' = 0{,}62$ and $tg\delta = 0{,}354$. Below are being presented the obtained results after simulating the heating process of the wet potato flakes in the microwave field.

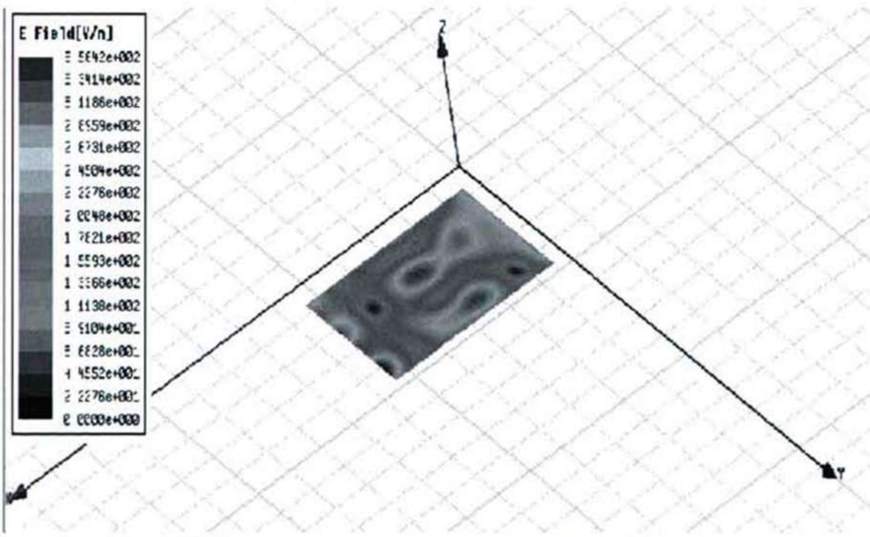

Figure 2. Electric Field Distribution Through the Dielectric

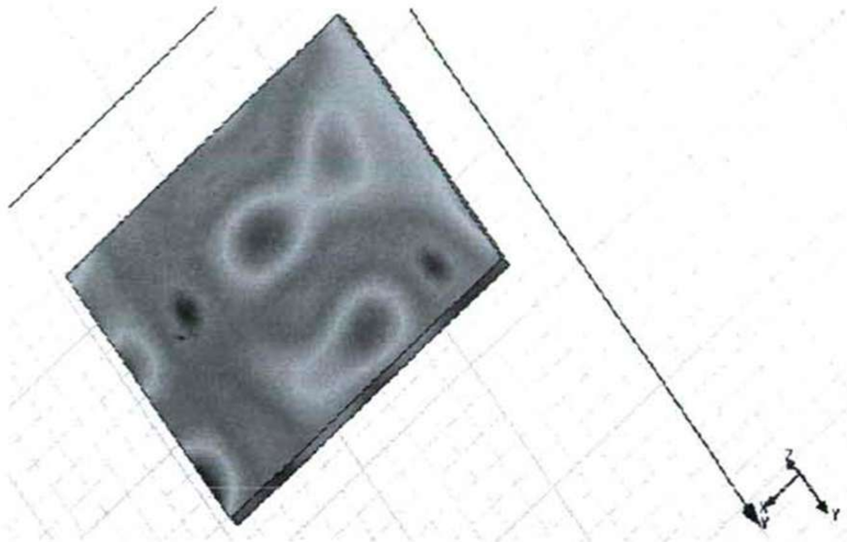

Figure3. Electric Field Distribution Through the Dielectric

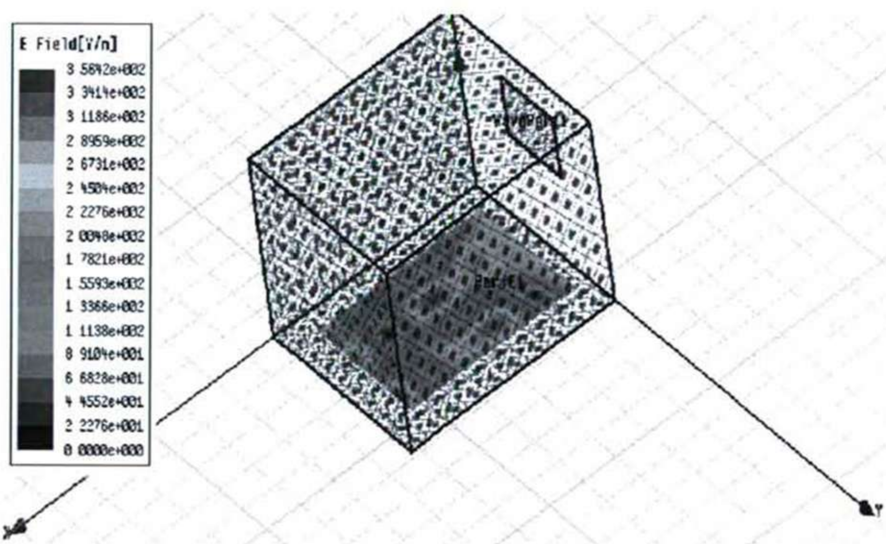

Figure 4. Electric Field Distribution Through the Dielectric . Boundary Conditions and the Position of the Waveport

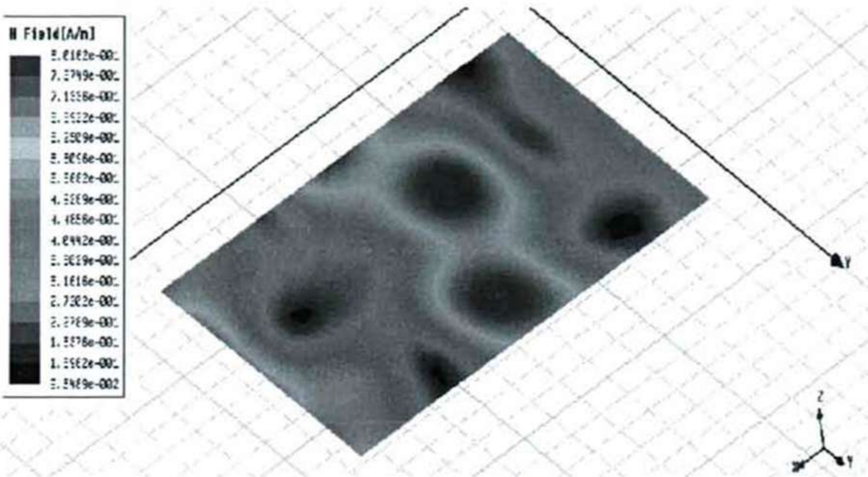

Figure 5. Magnetic Field Distribution Through the Dielectric

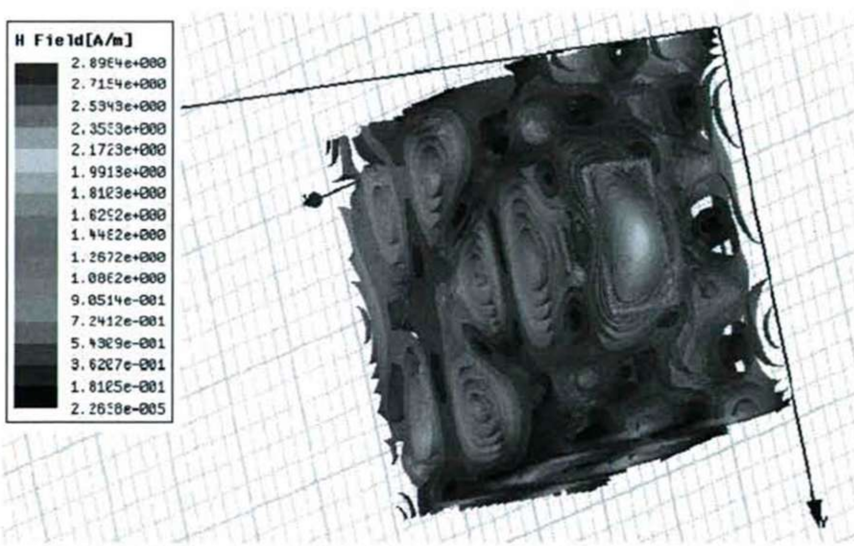

Figure 6. Magnetic Field Distribution Through the Waveguide and Dielectric

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4. CONCLUSIONS

Treating and drying using microwaves represents a technology that offers the material processor a new, powerfull and completely different tool with which it can be processed materials that can't be treated using conventional methods or which can improve the characteristic performances of materials.

From the analyze of numerical results it is wanted a homogenization of the electromagnetic field and implicitly of the thermal field wishing the elimination of the rotary plane and the possibility of using big dimensions of the recipients so that heating would be more uniform and efficient.

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